Chapter 8
Appurtenant Structures

8-1. Outlet Works

a. Foundation. If the dam's foundation consists of compressible soils, the outlet works tower and conduit should be founded upon or in stronger abutment soils or rock where less settlement and horizontal spreading will occur and where the embankment is lower. Seepage collars should not be used because adequate compaction is rarely achieved around the collars and because their presence may increase the separation of conduit sections should the embankment tend to spread. A drainage layer should be provided around the conduit in the downstream zone of embankments. Excavation slopes in earth for conduits should be no steeper than 1 vertical on 2 horizontal to facilitate adequate compaction and bonding of backfill with the sides of the excavation.

b. Concrete plug. A concrete plug should be used as backfill in rock cuts for cut-and-cover conduits within the core area to ensure a watertight bond between the structure and vertical rock surface. The plug, which can be constructed of lean concrete, should be provided over the length of the core contact area and extend up to the original rock surface. The substitution of hand-tamped earth fill is not considered an acceptable substitute for the lean concrete. Seepage collars should not be used except where they function for alignment control. In embankments having a random or an impervious downstream shell, horizontal drainage layers should be placed along the sides and over the top of conduits downstream of the impervious core.

c. Basins. Intake structure towers and outlet headwalls at stilling basins are often recessed into the embankment to reduce the length of conduit. Since the tolerable horizontal movements of these features are very small, they should be designed for earth pressure at rest, taking into account the surcharge effect of the sloping embankment and water table considerations. Sidewalls should also be designed for at rest earth pressures, considering surface effects from the sloping embankment where applicable.

d. Piers. When service bridge piers have been constructed concurrently with placement of the embankment fill, they have often suffered large horizontal movements. Construction of such piers should be delayed until after the embankment has been brought to grade, or at least until a large part of the embankment fill has been placed.

e. Outlet structures. Where outlet structures are to be located in active seismic areas, special attention must be given to the possibility of movement along existing or possibly new faults.

8-2. Spillway

a. Excavations. Excavations for spillways often require high side slopes cut into deposits of variable materials, often below groundwater table. If material from the spillway excavation is suitable for embankment fill, the stability of spillway slopes may be increased without increasing construction costs by excavating to flatter slopes. The stability of slopes excavated into natural materials is much more difficult to assess than that of slopes of properly constructed embankment. For excavation into natural soil deposits, detailed subsurface exploration including groundwater observations and appropriate laboratory tests on representative soils supply the information needed for slope stability analyses. When required excavation is in rock, the influence of structural discontinuities such as joints, faults, and bedding planes overshadows the properties of the intact rock as determined by tests on core samples. Consequently, detailed geologic studies and subsurface investigations, together with empirical data on natural and man-made slopes in the vicinity, are used for determining excavation slopes in rock and in clay shales.

b. Grout curtains. It is often necessary to extend grout curtains beyond the dam axis to include the abutment between the dam and spillway, as well as beneath and across the spillway structure. If the rock is of poor quality, it may be necessary to build concrete walls or provide revetment to protect against erosion toward the spillway.

8-3. Miscellaneous Considerations

a. Temporary slopes. Temporary excavation slopes behind training walls are commonly shown on contract plans as 1 vertical on 1 horizontal for pay purposes; however, for major cuts and for cuts in weak materials, the slopes should be designed for adequate stability and the required slopes shown on the contract drawings. Drainage of the backfill must be provided to reduce pressures against the walls to a minimum. The backfill should either consist entirely of free-draining material or have a zone of free-draining material adjacent to the wall containing a collecting pipe drain along the lower part of the backfill near the wall. Where there is room to do so, the most effective way to control drainage within the soil backfill is an inclined drainage blanket with a longitudinal drain (see EM 1110-2-2502, paragraph 6-6).

b. Channel slopes. Channel slopes adjacent to spillway and outlet structures must be designed to provide adequate factors of safety against slope failure. For some distance below stilling basins, the channel slopes and bed must be protected against scour with derrick stone and/or riprap; guidance on the design of such protection is furnished in EM 1110-2-1602 and EM 1110-2-1603.

c. Embankments. Special attention must be given to the junction of embankments with concrete structures such as outlet works, spillway walls, lock walls, and powerhouses to avoid piping along the zone. An embankment abutting a high concrete wall creates a tension zone in the top of the embankment similar to that occurring next to steep abutments. Horizontal joints should not be chamfered in the contact areas between embankment and concrete. A 10 vertical on 1 horizontal batter on the concrete contact surfaces will ensure that the fill will be compressed against the wall as consolidation takes place. The interface of an earth embankment abutting a high concrete wall should be aligned at such an angle that the water load will force the embankment against the wall. The best juncture of a concrete dam with flanking earth embankments is by means of wraparounds. Internal drainage provided beneath the downstream portion of the embankment should be carried around to the downstream contact with the concrete structure. Compaction contiguous to walls may be improved by sloping the fill away from the wall to increase roller clearances. Where rollers cannot be used because of limited clearance or where specifications restrict the use of rollers near walls, power tamping of thinner layers should be used to obtain densities equal to the remainder of the embankment. It may be desirable to place material at higher water contents to ensure a more plastic material which can adjust without cracking, but then the effects of increased porewater pressures must be considered.